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(54) **Output driver circuit**

(57) A circuit for driving a communication line includes a transformer (9) having a secondary winding (11) for supplying an output drive signal, and having a primary winding (13, 15) connected to conduct current through a control element (12, 14) that receives a control signal (135) which stabilizes the amplitude of output drive signal, independent of variation in supply voltage. A control circuit (100) produces the control signal in response to the difference of signals produced across conductive elements (110, 125) that are connected to separate current sources which supply currents determined by arithmetic relationships between the values of different supply voltages.

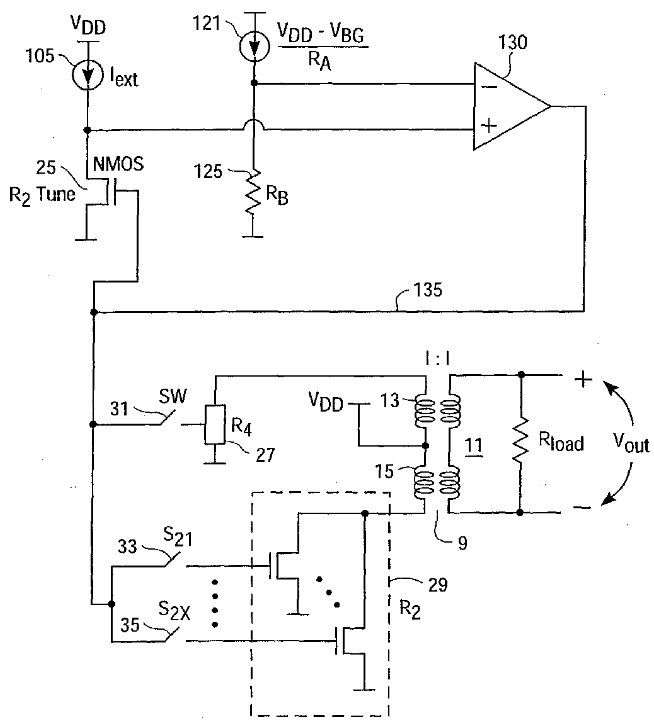

FIG. 3

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Description

[0001] Conventional line drivers commonly produce output signals with amplitudes that are limited by supply voltages. As integrated circuitry and process technologies improved, supply voltages reduced with associated reductions in the amplitudes of output drive signals.

[0002] Certain known schemes for increasing the amplitudes of output drive signals employ current-drive circuitry and transformer windings to produce output signals of greater amplitude than the supply voltages. However, such current-drive circuits commonly consume more power than voltage-drive circuitry and the inductive impedance inhibits rapid turn on/turn off operation.

[0003] Viewed from one aspect, the invention provides a driver circuit comprising:

a transformer including a center-tapped primary winding having end terminals and including a secondary winding in a selected turns ratio, with the secondary winding providing a circuit output;
a first voltage supply connected to the center tap of the primary winding and a control element connected to an end terminal of the primary winding for controlling conduction of current therethrough from the first voltage supply; and
a control circuit connected to supply control signal to the control element for controlling the conductivity thereof during conduction of current through the primary winding;
said control circuit including a current source serially connected at a first junction with an adjustable conduction element and a second current source serially connected at a second junction with a resistive element, and including an amplifier connected to the first and second junctions for supplying a control signal to the conduction element to adjust the conduction thereof in response to signals appearing at the first and second junctions.

[0004] In accordance with at least a preferred embodiment of the present invention, a center-tapped transformer and associated drive circuitry deliver output drive signals with greater amplitude than the supply voltages, and with the associated drive circuitry greatly simplified to reduce power consumption and the processing involved for integrating the drive circuitry. P-MOS circuitry connected to a high-side supply voltage is eliminated in favor of transformer coupling from an N-MOS low-side supply voltage. The transformer also isolates the output drive signal from ground for enhanced versatility in connecting to communication lines. Output wave shapes for universal driver applications may be controlled in response to activation of a plurality of variable conduction elements in accordance with a selected logical sequence.

[0005] Viewed from another aspect, the invention provides a driver circuit comprising:

a transformer having a center-tapped primary winding with end terminals and a secondary winding forming the circuit output;
a first source of voltage connected to the center tap of the primary winding;
first and second control means connected to the end terminals of the primary winding for controlling conduction of current therethrough in response to applied control signal;
circuit means including first and second current sources connected to respective first and second resistor means, and including an amplifier connected to receive the signals from the first and second resistor means for producing therefrom the control signal supplied to the first and second control means and to the first resistor means for controlling the conductivity thereof.

[0006] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a line-driver circuit including a transformer of selected turns ratio and single ended N-MOS driver circuits;
Figure 2 is a schematic diagram of one embodiment of a circuit for implementing the defining equation;
Figure 3 is a schematic diagram of an embodiment of the driver circuits including the circuit of Figure 2 and circuitry of energizing the primary windings of the transformer; and
Figures 4a and 4b are schematic diagrams of circuitry for producing the requisite current supplies in the circuit of Figure 3.

[0007] Referring now to Figure 1, there is shown a schematic diagram of a circuit including a transformer 9 of selected *n*:*m* turns ratio, and forming a basis for describing operation of one example of the present invention. Each single-ended input including N-MOS transistors 12,14 controls application of supply voltage V_{DD} to respective portions of the center-tapped primary winding 13,15. Specifically, it can be shown that the maximum output voltage Vout across the secondary winding 11 of the transformer 9 is determined.

$$V_{out} = V_{DD} \, x \, \frac{m}{n} \, x \, \frac{(½\frac{n}{m})^2 R_L}{R_2 + (½\frac{n}{m})^2 R_L} x \, 2 \qquad \text{(Equation 1)}$$

Thus,

$$V_{out} = 2\frac{m}{n} V_{DD} \left(\frac{R_L}{\left(2\frac{m}{n}\right)^2 R_2 + R_L} \right) \qquad \text{(Equation 2)}$$

$$V_{out} = 2\frac{m}{n} V_{DD}, \qquad \text{as } R_2 \to 0 \qquad \text{(Equation 3)}$$

Vout can be therefore greater than V_{DD}, if m > ½*n*.

R_2, as the equivalent resistance of the N-MOS transistor 14 in the ON conduction state, is substantially equal to the equivalent resistance R4 of the N-MOS transistor 12 in the ON conductive state. In addition, although the circuit may be driven or controlled single-endedly via transistor 12 or 14, the output V_{out} is differential due to the windings on the transformer 9.

[0008] From Equation 3, it should be noted that the value of resistance R_2 (or its equivalent, R_4) must be carefully controlled in order to produce output signal of stable amplitude that is independent of the supply voltage V_{DD}, and independent of process variations by which the N-MOS transistor 12 (and 14) is produced. Thus, from Equation 1, the stable value of output voltage may be set at V_{BG} (i.e., the conventional bandgap voltage):

$$V_{out} = V_{DD} \left(\frac{2\,R_{LOAD}}{R_{LOAD} + 4R_2} \right) = V_{CONSTANT} = aV_{BG} \qquad \text{(Equation 4)}$$

where m = *n* and *a* is an arbitrary ratio.

this is represented by a stable, internal voltage supply. Thus:

$$\frac{V_{DD}}{{}_aV_{BG}} = \frac{1}{2} + \frac{2R_2}{R_{LOAD}} \qquad \text{(Equation 5)}$$

and

$$R_2 = \left(\frac{V_{DD} \frac{aV_{BG}}{2}}{V_{BG}} \right) \frac{Rload}{2} \qquad \text{(Equation 6)}$$

and

$$R_2 \ \alpha \left(\frac{V_{DD} - \frac{aV_{BG}}{2}}{I_{EXT}} \right) \qquad \text{(Equation 7)}$$

where:

$$I_{EXT} = \frac{V_{BG}}{R_{EXT}} \qquad \text{(Equation 8)}$$

and R_{EXT} is an external resistor that behaves similarly to R_{LOAD}. Thus:

$$R_2 \ \alpha \frac{V_{DD}\text{-}V_{BG}}{I_{EXT}} \qquad \text{(Equation 9)}$$

for α chosen to be 2.

and the temperature effects of the external resistor and the load resistor substantially cancel.

[0009] Referring now to Figure 2, there is shown a schematic diagram of one circuit embodiment (100) for implementing the control of the equivalent resistance R_2. Specifically, current source, I_{ext}, 105 is connected to a variable equivalent resistance R_2 110, and current source 120 of value $\frac{V_{DD}\text{-}V_{BG}}{R_A}$ is connected to resistance R_B 125 in a bridge-type circuit configuration. The operational amplifier 130 has a pair of inputs 140, 145 that are connected to the common junctions of the respective current sources and equivalent resistances, as shown, to supply an output 135 to adjust the value of R_2 110 in response to the difference of voltages on the common junctions.

[0010] Referring, then, to Figure 3, there is shown the schematic diagram of one embodiment of the driver circuit of the present invention including the driver circuit and resistance-controlling circuit of Figures 1 and 2. Specifically, the adjustable resistance in the circuit of Figure 2 is shown as an N-MOS transistor 25, and the inputs to the primary windings 13, 15 of the transformer 9 are also shown as N-MOS transistors or equivalent resistors 27, 29, with switch arrays 31, 33, 35 shown connecting the gates thereof to receive the controlling output signal 135 from the amplifier 130. Such switches may be conventionally implemented as logic gates that are turned ON/OFF controllably. The ON/OFF status of switch 31 may serve as an input to the circuit, and the plurality of switches 33, 35 may be turned ON/OFF in a selected sequence to set rise and fall times or other wave forming functions of the output signal. The selected transformer ratio is conveniently set at 1:1, for example, to facilitate bifilar winding for size reduction and coupling efficiency between windings.

[0011] Referring now to Figure 4a, there is shown a schematic diagram of one circuit embodiment for implementing the current source I_{EXT} 105 in the circuit of Figure 3. Specifically, operational amplifier 150 is referenced to the voltage supply V_{BG} and receives the voltage drop across an external resistor R_{EXT} 151 to apply the amplified difference between the two voltages to the gate of N-MOS transistor 153. This transistor 153 is serially connected with one branch of current mirror 155 formed by P-MOS transistors 37, 39 that is connected between V_{DD} and R_{EXT} 151. The other branch of current mirror 155 supplies the current $I_{EXT} = \frac{V_{BG}}{R_{EXT}}$ from the V_{DD} voltage supply in the circuit of Figure 3.

[0012] Referring now to Figure 4b, there is shown a schematic diagram of one circuit embodiment for implementing the current source 121 of value $I = \frac{V_{DD}\text{-}V_{BG}}{R_A}$ in the circuit of Figure 3. Specifically, operational amplifier 123 is referenced to the voltage V_{BG}, and is connected to receive the voltage across resistor R_C 126 as one of the resistors in the circuit comprising the resistor R_C 126 and N-MOS transistor 127 and resistor R_C 129 connected between V_{DD} and ground. Operational amplifier 131 is connected to receive the voltage appearing across the combination of resistor Rc 126 and the N-MOS transistor 127, and is also connected to receive the voltage appearing across resistor R_A 133 connected to ground. The amplified difference of these two voltages is supplied to the gate of N-MOS transistor 136 which conducts current through one branch of the 'current mirror' circuit 138 that thus supplies the current $I = \frac{V_{DD}-V_{BG}}{R_A}$ for the circuit of Figure 3 through the other branch of the current mirror 138. All of the transistors and operational amplifiers and resistors may be conveniently fabricated on a common semiconductor substrate using conventional integrated circuit processing.

[0013] Therefore, the line driver of the present invention is capable of operating at low supply voltage to produce output drive signals with amplitudes greater than the supply voltage, and with stabilized signal amplitude that is substantially independent of variations in amplitude of the supply voltage, and with universally-compatible wave shaping under logic control.

Claims

1. A driver circuit comprising:

a transformer (9) including a center-tapped primary winding (13, 15) having end terminals and including a secondary winding (11) in a selected turns ratio, with the secondary winding providing a circuit output;
a first voltage supply (V_{DD}) connected to the center tap of the primary winding and a control element (12,14) connected to an end terminal of the primary winding for controlling conduction of current therethrough from the first voltage supply; and
a control circuit (100) connected to supply control signal to the control element for controlling the conductivity thereof during conduction of current through the primary winding;
said control circuit including a current source (105) serially connected at a first junction with an adjustable conduction element (110) and a second current source (120) serially connected at a second junction with a resistive element (125), and including an amplifier (130) connected to the first and second junctions for supplying a control signal (135) to the conduction element to adjust the conduction thereof in response to signals appearing at the first and second junctions.

2. The driver circuit according to claim 1, in which the first current source supplies current in proportion to the ratio of a second voltage supply to a first selected resistance value, and the second current source supplies current in proportion to the ratio of the difference between first and second voltage supplies to a second selected resistance value.

3. The driver circuit according to any one of claims 1 and 2, in which the end terminals of the primary winding of the transformer are each connected to a control element that communicates with the control circuit to receive the control signal therefrom for controlling the conduction of current therethrough.

4. A driver circuit comprising:

a transformer (9) having a center-tapped primary winding (13, 15) with end terminals and a secondary winding (11) forming the circuit output;
a first source of voltage (V_{DD}) connected to the center tap of the primary winding;
first and second control means (12,14) connected to the end terminals of the primary winding for controlling conduction of current therethrough in response to applied control signal (135);
circuit means (100) including first and second current sources (105, 120) connected to respective first and second resistor means (110, 125), and including an amplifier (130) connected to receive the signals from the first and second resistor means for producing therefrom the control signal supplied to the first and second control means and to the first resistor means for controlling the conductivity thereof.

5. The driver circuit according to claim 4 in which the first current source supplies a current proportional to a ratio of a voltage from a second source to first a selected resistance value; and in which

the second current source supplies a current proportional to a ratio of the difference of voltages from the first and second sources to a second resistance value; and

said control signal is selectively supplied to at least one of the first and second control means in response to an applied input signal.

6. The driver circuit according to claim 5 in which the second control means includes a plurality of variable conduction elements, and the control signal is selectively supplied to at least one of the variable conduction elements to control a parameter of signal produced at the circuit output.

7. The driver circuit according to claim 6 in which the plurality of variable conduction elements are activated in a selected sequence to alter the wave shape of signal produced at the circuit output.

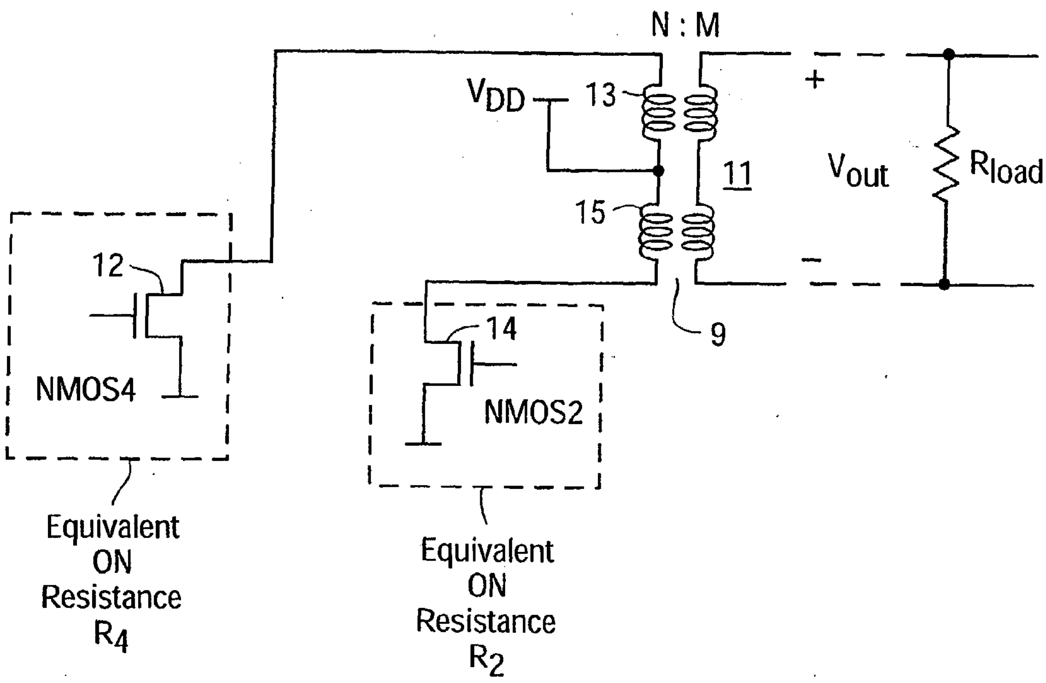
N : M
VDD
13
15
11
+
−
Vout
Rload
9
12
NMOS4
14
NMOS2
Equivalent ON Resistance R4
Equivalent ON Resistance R2

FIG. 1

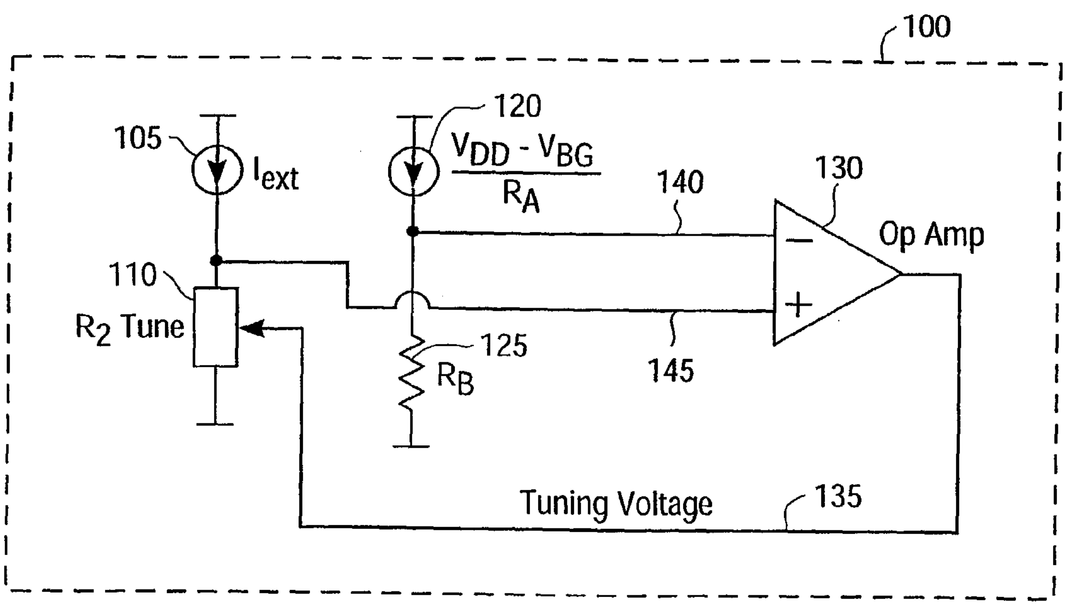
100
105
Iext
120
VDD - VBG / RA
140
130
Op Amp
110
R2 Tune
125
RB
145
Tuning Voltage
135

FIG. 2

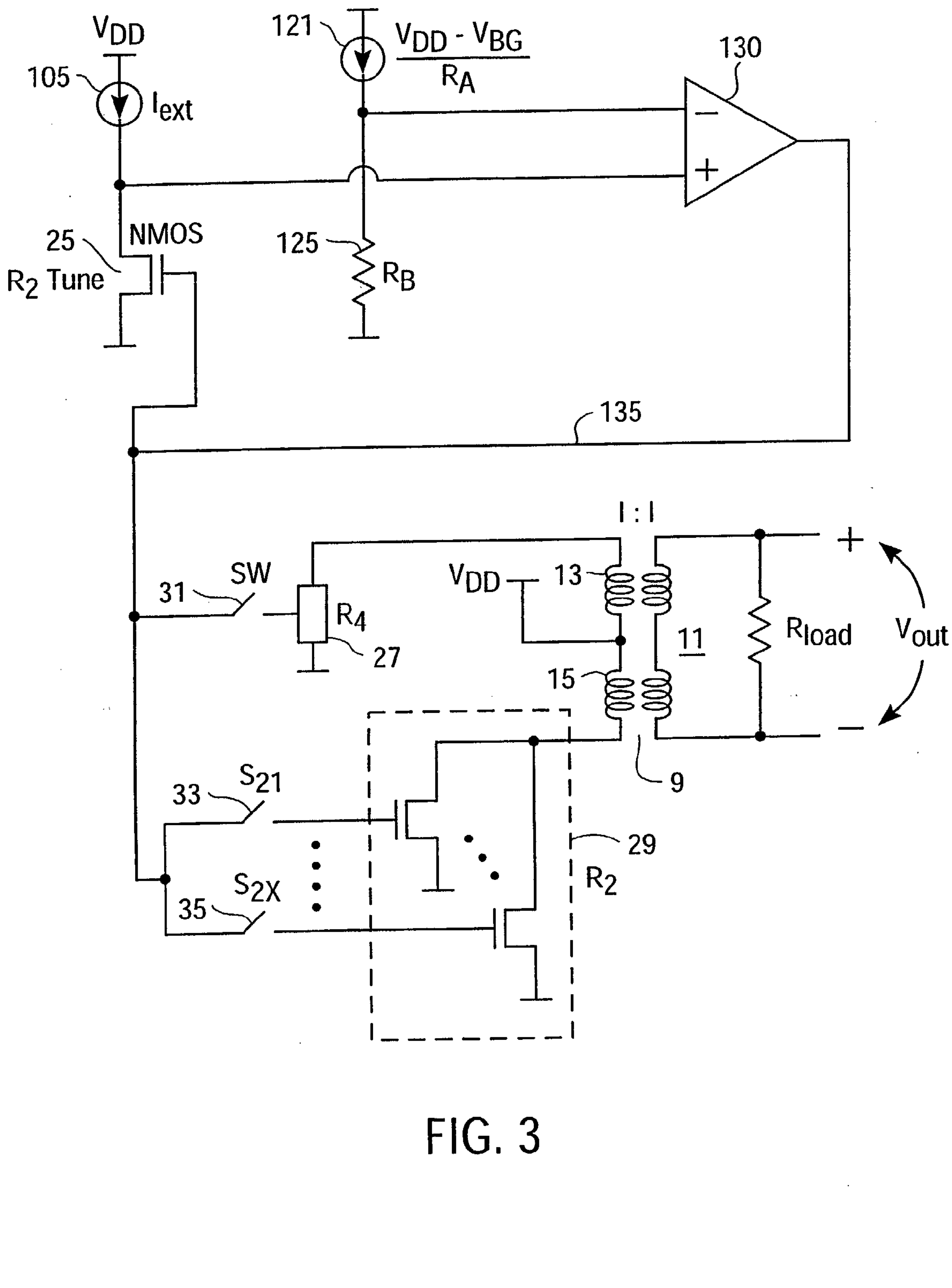
VDD
105
Iext
121
VDD - VBG
RA
130
NMOS
25
R2 Tune
125
RB
135
1:1
SW
31
R4
27
VDD
13
11
Rload
Vout
15
9
S21
33
29
R2
S2X
35

FIG. 3

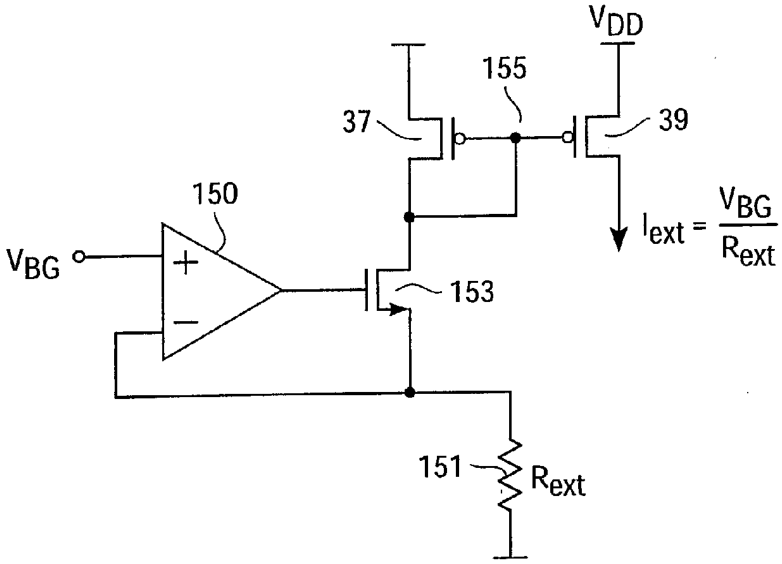
V_{DD}
155
37
39
150
V_{BG}
$I_{ext} = \frac{V_{BG}}{R_{ext}}$
153
151
R_{ext}

FIG. 4A

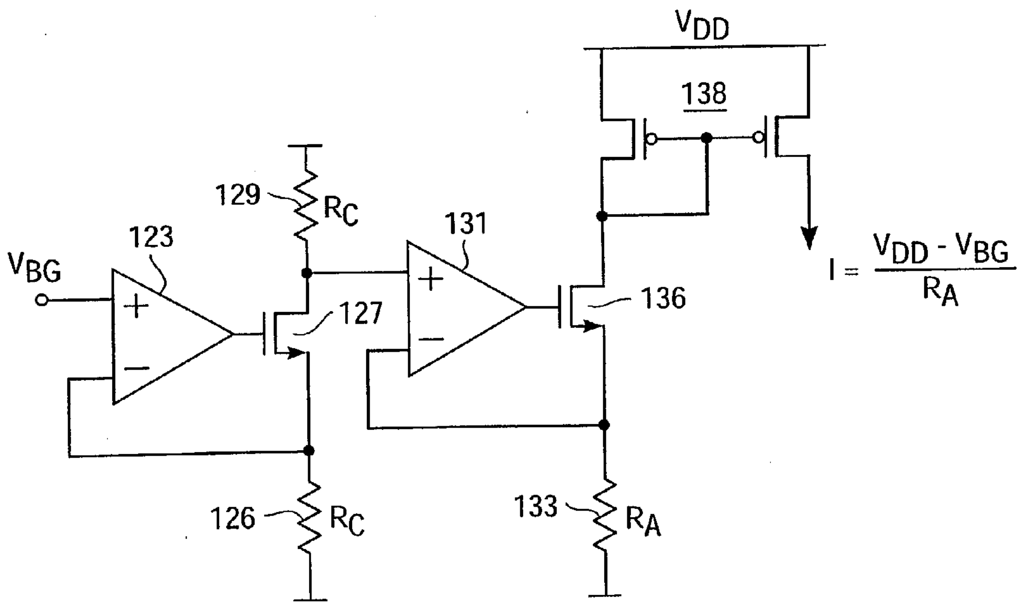
V_{DD}
138
129
R_C
131
123
V_{BG}
127
136
$I = \frac{V_{DD} - V_{BG}}{R_A}$
126
R_C
133
R_A

FIG. 4B

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EUROPEAN SEARCH REPORT

Application Number
EP 03 25 2118

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 05, 14 September 2000 (2000-09-14) & JP 2000 036844 A (NEC ENG LTD), 2 February 2000 (2000-02-02) * abstract * -----	1-7	H03K5/08 H04B1/58
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			H03K H04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	3 September 2003	Brown, J

CATEGORY OF CITED DOCUMENTS

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2000036844 A	02-02-2000	NONE	

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